NAVAL HEALTH RESEARCH CENTER

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ADJUSTMENTS TO SHIP HIT PROBABILITIES

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Report No. 96-25

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Report No. 96-25, supported by the Naval Medical Research and Development Command, Bethesda, MD, Department of the Navy, under Work Unit No. 63706N M0095.005-6503. The views expressed in this article are those of the authors and do not reflect the official policy or position of the Department of the Navy, Department of Defense or the U.S. Government. Approved for public release, distribution unlimited.

SUMMARY

Problem

The shipboard casualty projection system, SHIPCAS, is based on data from 80 naval operations during World War II. Ship defensive systems and weaponry have both changed considerably since the second world war, and the SHIPCAS model should reflect these changes in its hit probability estimates.

Objective

The present investigation seeks to improve SHIPCAS projections by adjusting model parameters to reflect advances in U.S. ship defensive systems as well as in the weapon systems of potential adversaries. The relative risks on hit probability associated with ship distance from land objective will also be assessed.

Approach

Ship hit probability adjustments were derived from quantitative responses of a subject matter expert (SME) panel. The subject matter experts, each with a naval engineering background, were asked to examine the factors affecting potential weapon strikes on contemporary ships and to quantify the likely hit probability change relative to attacks on reference ships during World War II. Additionally, coordinates of ships struck during combat operations were analyzed with respect to their nautical distance from the land objective.

Results

Consensus among panel members was achieved regarding the specific weapon systems posing potential threats to U.S. ships and the directional impact of each contemporary weapon system when compared with baseline hit probabilities. Ship hit probability projections were then derived for all contemporary weapons systems by averaging the projected impacts on hit probability given by the individual panel members. The longitudinal and latitudinal coordinates of successfully targeted vessels indicate that hit probabilities should incorporate the increased risk associated with ship proximity to land objective.

Conclusion

World War II-based ship hit probabilities need to be adjusted to reflect technological advances in defensive and offensive systems. The adjustments outlined in this report should generate revised projections that more accurately reflect future ship hit probabilities. This methodology allows the robustness of the original empirical data to be retained while incorporating weapon system advances, improved defensive capabilities, and littoral operation risk into hit probability predictions.

SHIPBOARD CASUALTY FORECASTING:
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Medical planning of naval operations requires forecasts of the likely numbers of casualties that would be sustained during combat scenarios. A shipboard casualty projection system, SHIPCAS,[1] has been developed to assist planners in determining the likely casualty incidence during combat operations. The SHIPCAS projections presently are based upon data from 80 naval operations and more than 800 ship strikes that occurred in the Pacific during World War II.[2,3] While it is important that casualty projections for future scenarios be grounded in empirical data, it is also recognized that ship defensive systems and offensive weaponry have changed since the naval combat of WWII, and that these changes may impact the probability of a modern weapon striking a ship.

The lack of recent involvement by U.S. forces in naval warfare has made the determination of future ship hit probabilities a difficult endeavor. While several models developed within the Department of Defense focus on the probable casualties which would be incurred in the event of a ship strike,[4,5] calculating the likely number of ship hits can involve a complex series of computations utilizing many tangible and less readily quantifiable factors. A few isolated peacetime and wartime incidents involving weapon strikes on U.S. ships have occurred in recent years; these incidents are so few in number that they do not provide an adequate statistical basis for modeling purposes. The current investigation utilizes the large amounts of data from the World War II Pacific operations as the baseline for hit rate forecasts and seeks to adjust these projections by incorporating the expected impacts of advances in weaponry, defensive systems, and delivery mechanisms. Differences in ship hit probability associated with varying distance from land objective are a secondary focus of the present investigation.

METHOD

Subject Matter Experts (SME) with backgrounds in ship structures, weaponry, and naval operations were solicited to participate on a panel quantifying changes to ship hit probability associated with advances in weaponry. Five former naval officers, representing a wide range of engineering and weapons expertise and averaging 28 years of naval service each, were selected as panel members.

Two weeks before the panel was to be convened, all SME members were provided with 218 pages of documentation on U.S. ships and Japanese offensive systems during World War II. For U.S. forces, this documentation included specifications of ships' armor and structure as well as information on Fleet air defense. For the opposing forces of the Japanese, the pre-meeting documentation included specifications of naval planes, bombs, projectiles, guns and ammunition, torpedoes, mines, and fire control equipment. All of the information on the Japanese forces was extracted from detailed reports compiled by the U.S. Technical Mission to Japan in 1945 and 1946, and archived at the Navy Historical Center in Washington, D.C.[6] Specifications of U.S. World War II warships were extracted from detailed reference sources.[7-9] The panel members were also provided with basic specifications of present-day missiles, underwater weapons, unguided rockets, guns, and bombs of manufacturers world wide, as well as more detailed specifications on U.S. present-day ship structures.[10-14]

The initial step taken once the panel was convened was to reach consensus on the specific weapon systems and delivery methods that represent potential threats to U.S. ships during contemporary naval combat operations. The SME panel members first reached agreement on broad categories of offensive weapons (e.g., bombs, torpedoes) representing threats and then reached consensus on specific subcategories of weapons (e.g., "dumb" torpedoes, wire-guided torpedoes) and their likely delivery mechanisms. Then the panel members discussed and reached

consensus regarding the directional impact of each contemporary weapon guidance system and delivery mechanism when compared with the baseline hit probabilities. That is, for each threat, the panel members reached agreement on whether the weapon specified represented an increase in hit probability, a decrease in hit probability, or no change in hit probability when contrasted with the overall likelihood of a ship being successfully targeted in the Pacific theater during World War II.

Panelists were not provided with the actual observed ship hit rates from the Pacific operations, but rather, made their judgments based on their expert knowledge of the offensive and defensive weaponry from the two time periods. The panel accomplished these activities, including a similar process to adjust casualty sustainment rates,[15] over 4 full days of meetings. Following this phase each panel member individually spent 40 hours quantifying what they believed the percentage change in hit probability would be for each weapon type and delivery mechanism, and documenting the factors that contributed to each proposed adjustment. Table 1 (see Appendix A) contains the offensive threats and associated delivery mechanisms upon which the panel agreed.

Lastly, longitudinal and latitudinal coordinate data were extracted from the deck logs and historical records[16] of 288 major combatant ships that were attacked and for which location and operation data were available. The coordinates of the land objective of each operation were plotted, and the distances in nautical miles between the objective and the targeted ships were computed.

RESULTS

ADJUSTMENTS FOR WEAPON SYSTEMS

The SME panel quantified the perceived impact on the baseline hit rate of each contemporary weapon system, and, when applicable, the platform used to deliver the weaponry.

Tables 2-6 (Appendix A) summarize the mean percentage increase or decrease in predicted hit probability for each weapon and delivery method using the overall hit likelihood during WWII Pacific operations as a reference point. Individual tables display the mean perceived percentage shift in hit probability separately for each weapon type and delivery system, as well as the increase or decrease for the weapon and delivery mechanism combined. The means were computed by eliminating the highest value and the lowest value from those provided by the 5 expert panelists and averaging across the three midrange scores. The standard deviations are also presented for each mean rating. The results of the panel's deliberations for each weapon are discussed in two sections -- effects on hit probability due to the weapon type and effects on hit probability due to the weapon delivery mechanism.

Bombs

Bomb Type Effects on Hit Probability The largest projected mean increase in hit probability among bomb types was for the *smart bomb*. The mean SME-derived shift in ship hit likelihood when comparing a contemporary adversary with this weapon against the baseline Pacific operations ship hit likelihood was a 90% increase in hit probability. This increase was attributed primarily to the increased precision in targeting associated with laser and television guidance. The panel held the view that the smart bomb's guidance systems allows greater accuracy in placement of this weapon, substantially increasing hit likelihood when contrasted with targeting capabilities during WWII.

The panel members were in agreement that the *gravity bomb*, when examined alone, represented no change (0% shift) in the hit likelihood when compared with overall WWII ship hit probability. The panel reasoned that if an adversary were able to penetrate within range to drop a gravity bomb, then it would have a similar probability of striking a ship as the overall hit likelihood of ships participating in the Pacific operations.

The panelist's ratings yielded a 51% projected increase in hit probability associated with the *air-launched dispenser bomb* when compared with the overall hit likelihood during the baseline operations. This prediction was due in part to the wide dispersion zone of this weapon -- a function of its many individual bomblets. A secondary consideration mentioned by the panel was the enhanced targeting capability associated with the dispenser bomb, a factor that would add to the likelihood of a hit on the intended target.

The SME panel rated the *rocket-assisted bomb* as having no change in hit probability when contrasted with ship hit likelihood during the Pacific engagements. The consensus was that the rocket-assisted bomb was susceptible to jamming of its guidance system by U.S. forces, a factor that would tend to decrease hit probability. A counterbalancing factor in the view of the panel, however, was the high speed at which this bomb travels. This speed would reduce the time from weapon release to possible impact and limit defensive maneuvering time. These two factors were viewed to offset each other, resulting in neither an increase nor decrease in hit probability.

Bomb Delivery Mechanism Effects on Hit Probability An average 80% decrease across panel responses was observed when comparing the likelihood of conventional aircraft being able to penetrate U.S. forces to get within bombing range with the overall ship hit likelihood during the baseline operations. The panel attributed this decrease in hit likelihood to U.S. modern detection capabilities, which can recognize conventional aircraft at long range, permitting interception before weapon release. Particular mention of the F-14 aircraft, which, with its capacity for extended operations, provides long-range protection of U.S. forces afloat from the conventional aircraft of potential adversaries.

In the view of the SME panel, stealth aircraft, if possessed by an adversary, would have a good possibility of penetrating U.S. forces to within bombing range. The mean shift in ship hit likelihood associated with the stealth aircraft as a delivery mechanism was a 91% increase over the ship hit probability during the baseline operations. The ability of the stealth to avoid

electronic detection, especially at night, and its better data transfer systems which rapidly insert launch orders into ordinance, were two main factors the panel cited as responsible for the increase in hit likelihood if used by an adversary as a bomb delivery system.

Guns

Gun-Type Effects on Hit Probability The largest projected mean increase in hit probability among gun types was for the *gatling gun.* The panel members most often cited the rapid rate of fire of the gatling when supporting the large predicted increase (142%) in hit probability compared with the baseline hit likelihood. In the view of the panel, this high rate of fire allows for a large number of hit attempts, thereby increasing the chance of a successful strike.

The panelist's ratings yielded an increase in hit probability associated with *laser-guided guns* when contrasted with the overall hit likelihood during Pacific operations. Laser guided guns were reported by the panel to have improved targeting, especially as it relates to a reduction in longer distance range errors. It was also noted that the weapon may be maneuvered to intercept with the guidance control system, a factor further improving accuracy and contributing to the SME-predicted increase in ship hit likelihood.

The panel likened *Non-laser-guided guns* to the guns used in World War II operations. In the view of the panelists, the non-laser-guided gun has experienced no substantial change in technology since the Pacific operations. Consequently, the SME panel expected no change in hit probability with this weapon when compared with the overall baseline hit rate.

Gunfire Delivery Mechanism Effects on Hit Probability The panelists were in agreement that penetration of a U.S. ship's or battle group's multilayered defensive envelope by an adversary's surface ship to within gunfire range would be unlikely. Because the "keep-out" zone that could be enforced was judged to be far beyond the range of ship-mounted guns, the panel

predicted a 92% decrease in hit probability when comparing this delivery mechanism with the hit likelihood during the baseline operations.

Similarly, the panel agreed that air-launched gunfire would have similar problems penetrating the defensive envelope of a ship or battle group. It would be very unlikely, in the panel's estimation, that an enemy aircraft could penetrate within strafing range. Consequently, the panel members predicted an average comparable decrease in hit probability of 90% for airborne delivery of gunfire.

Mines

Mine Type Effects on Hit Probability In evaluating the hit probability of *influence mines*, the panel underscored this type of weapon's reliable exploders and the fact that influence mines are difficult to detect and sweep. Additionally, it was reported that this type of mine also possesses sophisticated sensing and detonation devices that can be triggered in different manners. These factors contributed to the SME panel's mean 50% increase in hit probability when contrasting influence mines with the overall ship hit probability during the Pacific operations.

Contact mines were rated as having no change in predicted hit probability when contrasted with hit likelihood during the baseline operations. The panel cited the perceived lack of technological change in this specific weapon type -- the target must actually run into this type of mine -- as the main rationale in reaching a consensus opinion that hit probability would be unchanged.

The panel described the *encapsulated mine* as analogous to a homing torpedo in a mine casing. Panelists stated that this weapon is difficult to detect, hard to sweep, and very deadly once activated since it pursues its target. An average predicted hit probability increase of 98% was computed from the panel responses, reflecting the unique attributes of this weapon.

Torpedoes

<u>Torpedo Type Effects on Hit Probability</u> When judging the impact of *active homing torpedoes* on hit probability, the panel cited the use of active sonar and the much-improved modern fire control systems as two contributing factors to increased hit likelihood when compared with hit probabilities observed in the baseline operations. Though this increased likelihood was somewhat diminished by the belief that an active homing torpedo might be detected and subject to decoys and tactical maneuvers by the target vessel, a mean increase in hit probability of 125% was yielded from the panelist responses.

Passive homing torpedoes, which target noise such as that generated by a ship's propeller, were projected to have an even larger increase in expected hit probability (175%) than those guided by active homing systems. This weapon also benefits from a modern fire control system, and the panel judged it to be less susceptible to detection in transit, thus reducing the possibility of jamming and countermeasure attempts.

The SME panel also predicted an average 130% increase in likely hit probability for the *wire-guided torpedo*. Factors supporting this increase were the ability of this weapon to be guided to the target, better modern fire control systems, and less susceptibility to defensive maneuvering. The panel reported that the wire-guided torpedo has a shorter range than other types (due simply to the constrainment of the connected wire) but that this drawback was overcome by the ability of this torpedo to choose its target from a group -- an ability that allows the selection of high value targets.

The panel described the *dumb torpedo* as a straight-running torpedo similar to those used in the Pacific operations. This torpedo type is very susceptible to defensive maneuvering, and the

panel rated it as having no change in hit probability when compared with the overall baseline hit likelihood.

Torpedo Delivery Mechanism Effects on Hit Probability Torpedoes delivered by aircraft depend upon the plane to penetrate the intended vessel's or battle group's defensive envelope. The panel agreed that with a U.S. battle group's defenses, such an incursion would be unlikely. For this reason, an adversary's use of an aircraft as a torpedo delivery mechanism was projected to represent an 82% decrease in hit likelihood when comparing this delivery mechanism with the baseline operations hit probability.

The SME panel predicted a submarine-launched torpedo to have, on average, a 112% increased probability of a hit. The panel attributed the increase in hit probability to the difficulty for even modern systems to detect submarines. In the view of SME members, an undetected delivery platform such as a submarine could surprise the target vessel and allow less time for countermeasures to be employed.

Use of a surface ship as a delivery mechanism for a torpedo was rated to decrease the baseline hit probability by 88%. The panel's reasoning for this prediction was the expected difficulty of a surface ship to penetrate the defensive envelope of its intended target. Detection and engagement capabilities of the target were reported to have a longer range than the weapon capabilities, thus reducing the probability of a hit when using a surface ship for torpedo delivery.

Missiles

Missile Type Effects on Hit Probability The panel reported *ballistic missiles* to have a high likelihood by U.S. ships of detection and avoidance, in large measure due to their lack of a terminal guidance system. Defensive maneuvering by the target vessel, in the view of the SME panelists, would prevent a successful strike by a ballistic weapon in most cases. A mean decrease

in hit probability of 79% from the baseline hit likelihood was computed from the panel member responses.

The panel described *cruise missiles*, which have midcourse correction and terminal guidance systems, as a formidable threat against U.S. naval vessels if possessed by an adversary. Furthermore, they were described as long-range, fast, and exhibiting a low radar cross-section, all of which influenced the panel to predict a mean 107% increase in hit probability for a cruise missile when contrasted with the hit likelihood during the Pacific operations.

The panel characterized *guided missiles* as having extremely effective precision guidance systems with midcourse and terminal guidance capabilities. This advanced guidance system was a major factor contributing to the panel's predicted mean increase of 157% in hit likelihood for this missile type when compared with the baseline hit probability.

The panel classified the *anti-radiation missile* as a weapon that scatters fragmentation above the target vessel providing the potential for deck or bulkhead penetration. The SME members also described this missile as possessing an excellent guidance system, and the panel predicted a mean increase in hit probability of 117% for the anti-radiation missile when compared with the baseline hit likelihood.

<u>**Missile Delivery Mechanism Effects on Hit Probability**</u> Use of a surface ship from which to launch missiles was predicted to decrease the hit likelihood by 75% when contrasted with the overall ship hit probability during the Pacific operations. The panel's projected decrease was based on the expected difficulty of a surface ship to penetrate the multilayered defensive envelope of a U.S. ship or battle group.

Similarly, the SME panel predicted the conventional aircraft used as a missile delivery mechanism would decrease hit probability by 83%. The panel expressed the belief that an aircraft

or group of aircraft would most likely be detected and neutralized before penetrating the target's defenses.

The panelist ratings yielded an increase in hit likelihood over the baseline of 88% if stealth aircraft were used as the missile delivery mechanism. The panel's reasoning was that the stealth was difficult to detect, due to its electronic detection avoidance system, and could release its weapon closer to the target vessel, giving the ship less time for evasive maneuvers or jamming procedures.

Use of a submarine as a missile launch platform, in the view of the panel, would increase the probability of a hit by 143% when compared with overall hit likelihood during the Pacific operations. Modern submarines are very quiet and difficult to detect, factors the panel felt would help increase the probability of a successful missile attack by allowing the intended target less time to react or engage the delivery vessel.

ADJUSTMENTS FOR SHIP PROXIMITY TO LAND

The empirical data detailing the coordinates of the successfully targeted ships (n=288) indicate that two-thirds of the attacked ships were within 60 miles of their land objectives and that almost half of these ship hits were within 20 miles of their objective. The mean distance from the land objective to attacked ships was 73.7 nautical miles. Table 7 (Appendix A) displays the numbers of ships hit at various distances from the land objective by type of attack. Crude relative risks (rr) may be computed by comparing the percentages of ships struck in each nautical mile range with the percentage hit in the range centered around the mean (6.9% in the 60-80 nm range). Given that 30.9% of the ships hit were 0-20 nm from the land objective, a relative risk of 4.5 (30.9/6.9) is obtained. Similarly, relative risks for distances of 21-40 nm (rr=4.0), 41-60 nm (rr=1.4), 61-80 nm (rr=1.0), 81-100 nm (rr=0.6), 101-120 nm (rr=0.5), 121-140 nm (rr=0.5) and

141-160 nm (rr=0.14) were computed. These data indicate a lessening of hit risk with distance from operational target.

DISCUSSION

Any attempt at projecting the numbers of casualties likely to be sustained during naval combat engagements must take into consideration the number of ships likely to be hit as well as the WIA and KIA that would be incurred from these hits. Forecasting the likely number of hits, in turn, must take into consideration U.S. defenses and the offensive weaponry of potential adversaries. Toward this end, a Subject Matter Expert (SME) panel was convened to quantify the likely impact of recent advances in defensive and offensive weaponry on the ship hit rates observed during previous combat engagements.

Utilizing the hit rates during WWII Pacific operations as a baseline, and comparing the weapons inventories of the opposing sides for the baseline data with contemporary defensive and offensive armaments, the SME assigned a percentage shift (increase or decrease) in hit probability to each weapon system that a potential adversary might possess. Mean hit probability adjustments were then calculated across the SME panel for each weapon and associated delivery mechanism.

The SME panel ratings indicated the panelist's beliefs that with most conventional weaponry and delivery mechanisms, U.S. defenses have outpaced offensive technology, which should yield a reduced hit rate when compared with the baseline data. However, should the U.S. engage an enemy with the latest generation of weapons (i.e., smart bombs, laser-guided projectiles, passive homing torpedoes) and delivery systems (submarines, stealth aircraft) the hit probabilities would likely be greater than those observed in the baseline Pacific operations.

Presently few potential adversaries possess advanced technology such as cruise missiles and stealth aircraft; however, geopolitical dynamics can alter previous alliances, and the international

arms trade continues to increase capabilities of even the smallest countries. The SHIPCAS projection system allows casualty forecasts to be tailored to changing weapons inventories of an adversary rather than to make projections based upon a static scenario. Further, the planner will input the likely percentage of overall weapons usage associated with each system within an adversary's inventory -- a calculation that will incorporate not only what a particular adversary possesses, but their willingness to use a particular weapon, considering factors such as hit likelihood, economic cost, and probable U.S. response. This information, combined with input delineating the numbers of ships expected to be operating at various distances from the land objective, will allow present-day ship hit projections to be computed utilizing large amounts of empirical data and adjusting for technological advances.

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APPENDIX A

TABLE 1. OFFENSIVE THREATS AND ASSOCIATED DELIVERY METHODS

BOMBS	DELIVERY METHODS
Smart	Stealth Aircraft
Gravity	Conventional Aircraft
Dispenser	
Rocket-Assisted	

GUNS	DELIVERY METHODS
Laser-Guided	Air Launch
Non-Laser-Guided	Surface Ship Launch
Gatling	

MINES	(No associated delivery methods)
Influence	
Contact	
Encapsulated	

TORPEDOES	DELIVERY METHODS
Active Homing	Air Launch
Passive Homing	Submarine Launch
Wire-Guided	Surface Ship Launch
Dumb	

MISSILES	DELIVERY METHODS
Ballistic	Surface Ship Launch
Cruise	Submarine Launch
Guided	Stealth Aircraft
Anti-Radiation	Conventional Aircraft

TABLE 2. MEAN PERCEIVED SHIFTS IN SHIP HIT PROBABILITIES: CONTEMPORARY BOMBS CONTRASTED WITH OVERALL WWII U.S. SHIP HIT LIKELIHOOD

	MEAN SHIFT IN % HIT PROBABILITY	STANDARD DEVIATION
BOMB TYPE		
Smart	+90.0	10.0
Gravity	0.0	--
Dispenser	+34.3	5.1
Rocket-Assisted	0.0	--
DELIVERY METHOD		
Conventional A/C	-80.0	8.7
Stealth A/C	+90.7	86.5

BOMB TYPE AND DELIVERY MECHANISM	COMBINED SHIFT IN % HIT PROBABILITY
Smart with Conventional A/C	+10.0
Smart with Stealth A/C	+180.7
Gravity with Conventional A/C	-80.0
Gravity with Stealth A/C	+90.7
Dispenser with Conventional A/C	-45.7
Dispenser with Stealth A/C	+125.0
Rocket-Assisted with Conventional A/C	-80.0
Rocket-Assisted with Stealth A/C	+90.7

TABLE 3. MEAN PERCEIVED SHIFTS IN SHIP HIT PROBABILITIES: CONTEMPORARY GUNS CONTRASTED WITH OVERALL WWII U.S. SHIP HIT LIKELIHOOD

	MEAN SHIFT IN % HIT PROBABILITY	STANDARD DEVIATION
GUN TYPE		
Laser-Guided	+66.7	50.3
Non-Laser-Guided	0.0	--
Gatling	+141.7	101.0
DELIVERY METHOD		
Surface Ship Launched	-91.7	2.9
Air Launched	-90.0	5.0

GUN TYPE AND DELIVERY MECHANISM	COMBINED SHIFT IN % HIT PROBABILITY
Laser-Guided with Surface Ship Launch	-25.0
Laser-Guided with Air Launch	-23.3
Non-Laser-Guided with Surface Ship Launch	-91.7
Non-Laser-Guided with Air Launch	-90.0
Gatling with Surface Ship Launch	+50.0
Gatling with Air Launch	+51.7

TABLE 4. MEAN PERCEIVED SHIFTS IN SHIP HIT PROBABILITIES: CONTEMPORARY MINES CONTRASTED WITH OVERALL WWII U.S. SHIP HIT LIKELIHOOD

	MEAN SHIFT IN % HIT PROBABILITY	STANDARD DEVIATION
MINE TYPE		
Influence	+46.7	5.8
Contact	0.0	--
Encapsulated	+65.0	18.0

DELIVERY METHOD

No delivery methods are considered for mines due to the nature of this weapon type.

TABLE 5. MEAN PERCEIVED SHIFTS IN SHIP HIT PROBABILITIES: CONTEMPORARY TORPEDOES CONTRASTED WITH OVERALL WWII U.S. SHIP HIT LIKELIHOOD

	MEAN SHIFT IN % HIT PROBABILITY	STANDARD DEVIATION
TORPEDO TYPE		
Active Homing	+91.7	14.4
Passive Homing	+141.7	99.3
Wire-Guided	+97.0	46.1
Dumb	0.0	--
DELIVERY METHOD		
Air Launched	-81.7	7.6
Submarine Launched	+88.3	58.0
Surface Ship Launched	-87.7	11.7

TORPEDO TYPE AND DELIVERY MECHANISM	COMBINED SHIFT IN % HIT PROBABILITY
Active Homing with Air Launch	+10.0
Active Homing with Submarine Launch	+180.0
Active Homing with Surface Ship Launch	+4.0
Passive Homing with Air Launch	+60.0
Passive Homing with Submarine Launch	+230.0
Passive Homing with Surface Ship Launch	+54.0
Wire-Guided with Air Launch	+15.3
Wire-Guided with Submarine Launch	+185.3
Wire-Guided with Surface Ship Launch	+9.3
Dumb with Air Launch	-81.7
Dumb with Submarine Launch	+88.3
Dumb with Surface Ship Launch	-87.7

TABLE 6. MEAN PERCEIVED SHIFTS IN SHIP HIT PROBABILITIES: CONTEMPORARY MISSILES CONTRASTED WITH OVERALL WWII U.S. SHIP HIT LIKELIHOOD

	MEAN SHIFT IN % HIT PROBABILITY	STANDARD DEVIATION
MISSILE TYPE		
Ballistic	-78.7	12.1
Cruise	+73.3	34.0
Guided	+123.3	153.1
Anti-Radiation	+85.0	99.6
DELIVERY METHOD		
Surface Ship Launched	-75.0	15.0
Submarine Launched	+110.0	40.4
Stealth Air	+87.7	97.3
Conventional Air	-83.3	11.5

MISSILE TYPE AND DELIVERY MECHANISM	COMBINED SHIFT IN % HIT PROBABILITY
Ballistic Missile with Surface Ship Launch	-153.7
Ballistic Missile with Submarine Launch	+31.3
Ballistic Missile with Stealth Air Launch	+9.0
Ballistic Missile with Conventional Air Launch	-162.0
Cruise Missile with Surface Ship Launch	-1.7
Cruise Missile with Submarine Launch	+183.3
Cruise Missile with Stealth Air Launch	+161.0
Cruise Missile with Conventional Air Launch	-10.0
Guided Missile with Surface Ship Launch	+48.3
Guided Missile with Submarine Launch	+233.3
Guided Missile with Stealth Air Launch	+211.0
Guided Missile with Conventional Air Launch	+40.0
Anti-Radiation Missile with Surface Ship Launch	+10.0
Anti-Radiation Missile with Submarine Launch	+195.0
Anti-Radiation Missile with Stealth Air Launch	+172.7
Anti-Radiation Missile with Conventional Air Launch	+1.7

TABLE 7. NUMBER OF SHIP ATTACKS BY DISTANCE FROM LAND OBJECTIVE AND WEAPON TYPE; U.S. WARSHIPS, 1942-45

Distance (nautical miles)	Bomb	Coastal Gunfire	Naval Gunfire	Aircraft Strafing	Kamikaze	Air Torpedo	Ship Torpedo	Sub Torpedo	Gunfire Friendly	TOTAL	% of all Incidents
0-20 nm	8	11	5	--	48	3	6	--	7	89	30.9%
21-40 nm	7	3	5	1	54	1	4	--	1	79	27.4%
41-60 nm	5	2	2	--	16	1	--	--	1	27	9.4%
61-80 nm	2	--	1	--	16	--	--	--	1	20	6.9%
81-100 nm	1	--	1	1	9	--	--	--	--	12	4.2%
101-120 nm	--	1	--	--	9	--	--	--	--	10	3.5%
121-140 nm	1	--	2	--	4	1	--	--	2	10	3.5%
141-160 nm	1	--	--	--	--	--	--	1	1	3	1.0%
161-180 nm	--	--	--	--	1	--	--	--	--	1	0.3%
181-200 nm	--	--	--	--	2	--	--	1	--	3	1.0%
201-220 nm	2	--	1	--	--	1	--	2	1	7	2.4%
221-240 nm	--	--	--	--	2	--	--	--	--	2	0.7%
240-300 nm	1	--	1	--	5	--	--	3	--	10	3.5%
301-500 nm	5	1	1	1	3	--	--	1	3	15	5.2%

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE 30 July 96	3. REPORT TYPE AND DATE COVERED Final 8/95-8/96

4. TITLE AND SUBTITLE
Shipboard Casualty Forecasting: Adjustments to Ship Hit Probabilities

5. FUNDING NUMBERS
Program Element: 63706N
Work Unit Number:
M0095.005-6503

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8. PERFORMING ORGANIZATION
Report No.
96- 25

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Naval Medical Research and Development Command
National Naval Medical Center
Building 1, Tower 2
Bethesda, MD 20889-5044

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT

Approved for public release; distribution is unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

Adjustment factors needed to contemporize World War II-based hit probabilities of the SHIPCAS casualty projection model were investigated. Subject Matter Experts provided quantitive responses corresponding to the perceived shifts in hit probability associated with each present-day weapon system when compared to the baseline hit rate. The largest projected increases in hit probability were associated with submarine-launched guided missiles and submarine launched torpedos with passive homing systems. Hit probabilities associated with individual weapon systems ranged from a 90% decrease to a 233% increase when compared to WWII ship hit likelihood. Empirical data also indicated that ship hit likelihood decreased with distance from land objective.

14. SUBJECT TERMS Ship hit probability, Subject Matter Expert Panel Shipboard Casualty Projections, Littoral operations, weapon type and delivery mechanism	15. NUMBER OF PAGES 25
	16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	Unlimited

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. Z39-18
298-102